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Response of Irish Potato (Solanum tubersome L.) to Potassium and Organic Fertilization in Gozamin Woreda, East Gojjam zone, Ethiopia

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Abstract
Though chemical fertilizer application has been in use for more than five decades in Ethiopia, crop productivity has not been grown as expected due to poor nutrient use efficiency and nutrient imbalance. This experiment was, thus, conducted to determine the effect of potassium (K) and farm yard manure fertilizer on tuber yield and quality of potato. Potato variety "Belete" was used as a test crop to evaluate the response of K and FYM. The treatments were four levels of potassium (K) (0, 70, 140, 210 kg K ha^{-1}) applied as sulphate of potash (K_2SO_4) and three levels of farm yard manure (0, 7.5 and 15 t ha^{-1}) in factorial combination. The design used was split plot with three replications. The main plot and split plot factors were FYM and K-level, respectively. A plot of 3.75 m x 2.1 m was used with intra and inter row spacing of 30 and 75 cm, respectively. A distance of 0.3, 0.5 and 1 m gap was left between sub plots, main plots and blocks, respectively. Nitrogen (N) and phosphorus (P) were applied at 81 and 69 kg ha^{-1} as urea and DAP, respectively, uniformly to all plots. Nitrogen was applied in two split, at planting and after tuber initiation (as side dressing).

1. Introduction

Chemical fertilizer application has been under use for about four decades in Ethiopia. Since then the level of small holder farmers using these fertilizers has been grown and reached at 44% in 2005 (Mesfin Admasu, 2009) and coverage of 40% of the cultivated land but at dosage below the optimal level (Gete Zeleke et al., 2010). Statistical evidences confirmed that the production and yield growth of the country's cereal crops in the past five years were 12 and 6%, respectively. This explains, however, the contribution of increased cultivated land is quite immense as compared to the rise of fertilizer purchase and utilization at country level. The limited contribution of fertilizer input to productivity of Ethiopian agriculture is attributed to poor fertilizer use efficiency (unit yield obtained per unit nutrient added).

Nutrient balancing challenge, among a range of factors, is believed to be significantly dictating the lower fertilizer use efficiency of Ethiopia. Despite its being primary essential plant nutrient for plant growth and development, Potassium (K) fertilizer application, for example, was not practiced in the country in response to the conclusion of Murphy (1968) saying" Ethiopian soils are rich of K containing minerals". Instead nitrogen (N) and P_2O_5 were the only elements added to our soils through Urea and DAP, respectively for the last four decades.

However, as time goes, intensive weathering and subsequent loss of K by leaching, crop mining and erosion can deplete the K minerals of soils (Foth, 1951). Potassium deficiency typically occurs in highly weathered tropical (Oxisols, Ultisols) and coarse textured soils (Saifullah et al., 2002). Moreover, the human aggravated soil acidification process which is intense in many parts of the country has been found potassium deficient (Wassie Haile and Shiferaw Bokie, 2011). Full applied N utilization by the crop is also ensured when potassium supply is adequate (Mengel and Kirkiby, 1987).

Potato thrives in well drained, loose and fertile acidic soil of pH 5-5.4 without lime application (Greensil, 1978; Cotner, 1985). Hartmann et al. (1988) verified that potato is heavy mineral nutrient user crop. One tone potato tuber yield removes about 5.41 kg of K_2O from a hectare of land (FAO, 2006) indicating its high responsiveness to applied K as compared to cereals which do not respond readily to its application (Grewal & Trehan, 1993). Quality (starch concentration in tubers) and quantity of tuber will be affected whenever K deficiency encounters (Patent and Bilderback, 1982; FAO, 2006).

Depending on the climate, cultural practice, variety and soil type potato needs 80-150, 60-100, and 60-150 kg N, P_2O_5 and K_2O ha^{-1} for optimum productivity (FAO, 2006).These points justify that productivity of high K demanding vegetable crops such as potato particularly on acidic soils can be enhanced through supplemental potassium fertilizer.

Response of fertilizers and rates of application vary widely with climate, crop husbandry practices and soil type (Hartmann et al., 1988). Tsedale (1983) have found a positive response of K application (210 kg ha^{-1}) in one of the four different soils at Hararghe Highland. Similarly, the reports of Abay Ayalew and Sheleme Beyene (2011) came up with an insignificant potato yield response to K fertilizers at non-acidic soils of Angacha Research Station. On the other hand, Wassie Haile and Shiferaw Bokie (2011) reported significant potato tuber yield response at 150 kg ha-1 K as compared to the control at the highland and acidic soils of Chencha and

Hagereselam areas of southern Ethiopia. The work of IAR (1987) on tomato at Nazareth in the early 1980s also confirmed a trend of positive response for k fertilization.

Potato is an important cash and food crop grown in about 5174.11 hectares in East Gojjam. Despite its low productivity (10.39 tonnes ha^{-1}), 26% of the total regional potato tuber yield is shared by this zone (CSA, 2011). This productivity is in fact above the regional and national averages but below the Europeans' average (30-40 tones ha^{-1}). This low productivity is often attributed to the absence of balanced fertilization (FAO, 1991). Realizing the importance of K^+ in plant nutrition and its high removal from soil by crops, and the availability of limited studies conducted so far in Ethiopia, fundamental studies on K fertilization in combination with other organic amendments need to be studied in order to enhance potato production and productivity sustainably. Based on such facts and information an experiment will be conducted to determine the effect of different levels of potassium (K) fertilizer on tuber yield of potato and its interactive effect with farm yard manure on the tuber yield and quality of potato.

Though chemical fertilizer application has been in use for more than five decades in Ethiopia, grain production has not been grown as expected due to poor nutrient use efficiency and nutrient imbalance. Potassium (K) fertilizer application, for example, was not practiced in the country, inspite of the fact that tuber crops like potato requires tremendous amount of it and recurrent leaching removes a lot per annum in rainfall areas. Horticultural crops in general and potato in particular do have a range of responses to applications of K fertilizer (Tsedale ,1983; Abay Ayalew and Sheleme Beyene ,2011, Wassie Haile and Shiferaw Bokie ,2011; IAR ,1987). Response of chemical fertilizers and rates of application vary widely with climate, crop husbandry practices and soil type (Hartmann et al., 1988). Therefore, this experiment was conducted to determine the effect of different levels of potassium (K) fertilizer on tuber yield of potato and its interactive effect with farm yard manure on the tuber yield and quality of potato.

2. MATERIALS AND METHODS

Potato variety "Belete" was used as a test crop to evaluate its response to increasing levels of K and FYM. The treatments were four levels of potassium (K) (0, 70, 140, 210 kg K ha^{-1}) applied as sulphate of potash (K_2SO_4) and three levels of farm yard manure (0, 7.5 and 15 t ha^{-1}) in factorial combination. The design used was split plot with three replications. The main plot and split plot factors were FYM and K-level, respectively. A plot of 3.75 m x 2.1 m was used with intra and inter row spacing of 30 and 75 cm, respectively. The experiment was conducted for one seasons (2014) under rain fed condition, from June to October. A distance of 0.3, 0.5 and 1 m gap will be left between sub plots, main plots and blocks, respectively. Nitrogen (N) and phosphorus (P) were applied at 81 and 69 kg ha^{-1} as urea and DAP, respectively, uniformly to all plots. Nitrogen was applied in two split, at planting and after tuber initiation (as side dressing). All doses of P and K were applied at planting. All cultural practices, such as weeding, earthing up, etc., will be carried out equally for all treatments.

3. Result and Discussion

Results of data recorded on growth, yield, quality, wilt incidence and soil chemical parameters are presented and discussed sequentially as follows:

3.1. Soil Analysis result

Prior to the execution of the experiment 36 subsamples were collected and subjected to laboratory test for the sake of biophysical information of the site. The tested parameters were made by following standard procedures. According to the result indicated (Table 1), the pH of the experimental soil was 5.5. This makes the soil to have an acidic property. In line with this, other important parameters were also analyzed with this.

Table 1. Major soil physicochemical analysis result of the experimental soil

Depth of soil	pH	Tex. class	OM(%)	TN (%)	AV. P (ppm)	CEC (cmol + charge/kg)	EA	Ex. Ca(cmol + charge/kg)	Av K (kg/ha)
0-30 cm	5.5	Clay	1.5	0.06	2.1	12	1.6	2.5	60
30-60 cm	5.5	Clay	1.3	0.04	1.9	13	0.6	3.5	51
Method of Analysis	1:2	Hydrometer method	Walkley & Black	Kjeldahl	Olsen	Ammonium acitate extraction			

There is a general decrease of Om , Av. P and EA down the profile. The fertility status of the experimental site is low to medium range. However, the acidity level needs reclamation to produce sensitive crops. The analysis result does not reflect subsoil acidity. Available K is in the range of low status.

3.2. Effects of potassium and farmyard manure on tuber N, P and K content

Nitrogen (g/100g) : The analysis of variance for the main effects of farmyard manure (FYM) and potassium (K) applications showed significant (P>0.05) difference on tuber nitrogen content (Table 1). Significantly higher response have been found at higher rates of FYM (15 t ha^{-1}) and 210 kg ha^{-1}.The better response to the larger amount of K (210 t ha^{-1}) in this study may be attributed to the severe frost which occurred during the growing period because K imparts resistance to frost injury (Grewal and Singh, 1980). Potassium fertilization significantly increased the yield of marketable size tubers at the cost of small and medium size tubers (Singh, 1999). The mean increase in the yield of large-sized tubers may be attributed to the stimulating effect of K on photosynthesis, phloem loading and translocation as well as synthesis of large molecular weight substances within storage organs (Beringer, 1978), contributing to rapid bulking of the tubers.

Phosphorous (g/100g): The analysis of variance for the main effects of farmyard manure (FYM) and potassium (K) applications showed significant (P>0.05) difference on tuber phosphrus content (Table 1). Like that of the response of the treatments to N content, main effects of FYM and K were pronounced in tuber P content. Tuber P content was positively and significantly affected at each level of FYM and K. This result is in line with several findings across the globe that P assimilation.

Potassium (g/100g): The analysis of variance for the main effects of farmyard manure (FYM) and potassium (K) applications showed significant (P>0.05) difference on tuber potassium content (Table 1). Application of 5t FYM alone or in combination with K was found to have a significant effect on potato tuber yield, K concentration, K uptake and recovery from applied fertilizers. Application of 210 kg K ha^{-1} was found to be the best treatment as it increased K fertilizer use efficiency by over 10%. Both FYM and K application had a positive effect on tuber K concentration.

Table 2. Nitrogen, phosphorus, potassium, starch and sugar contents as affected by different rates of Farmyard manure and potassium

FYM (t/ha)	N (g/100g)	P (g/100g)	K (g/100g)	Starch (g/100g)	Sugar(g/100g)
0	1.48ab	0.23a	1.3a	7.45a	1.17a
7.5	1.58b	0.25b	1.48b	8.98b	1.39b
15	1.67c	0.27c	1.7c	10.98c	1.58c
LSD (0.05)	0.08	0.01	0.07	0.03	0.08
CV (%)	5.63	2.87	5.72	4.5	7.01
K (kg/ha)					
0	1.28a	0.23a	1.28a	7.77a	1.13a
70	1.36a	0.24b	1.36a	8.56b	1.19a
140	1.74b	0.26c	1.56b	9.6c	1.50b
210	1.94c	0.27d	1.78c	10.64d	1.69c
LSD (0.05)	0.09	0.01	0.09	0.01	0.09
CV (%)	5.63	2.87	5.72	2.87	7.9

* Means followed by the same letters in a column are not significantly (p<0.05) different.

3.3. Effect of FYM and K on potato tuber processing quality (starch and sugar)

As can be seen in Table 1, starch and sugar content of tubers is positively and significantly affected by both FYM and K applications. The responses are more pronounced as both factors increase in levels. The crucial importance of potassium in quality formation is related to its role in promoting synthesis of photosynthates in potato leaves and their transport to the tubers and to enhance their conversion into starch, protein and vitamins, hence overall tuber bulking and tuber composition depend on K nutrition.

Sugar contents of potato tubers were also affected with K application. Sugar content was relatively higher in tubers treated with higher K as compared to low level treatments. The difference between applied K levels was significant that indicates that use of higher rates of K in potato would tend to enhance sugar contents in potatoes. Similarly, Kamal et al., (1974 b) reported increased sugar content in potato tubers with K application. As regards the relationship between potassium source and starch production, Buchner (1951) reported that in chloride-treated plants the reducing sugar content was less than that with sulphate.

3.4. Interaction effects of FYM and K application on N, P and K content of potato tubers

All N, P and K content of potato (var. Belete) have been positively influenced by the interaction effect of FYM and K. The interaction effect has influenced N, P and K in increasing order. At 0 t ha^{-1} , nutrient compositions of tuber grow steadily from 0 to 210 kg k ha^{-1} (Figure 1). However, accelerated increase of P and K composition was observed at 15 t ha^{-1} FYM rate and 140 kg K ha $^{-1}$. The N composition has reached at its maximum peak at 15 t ha^{-1} FYM and 210 kg K ha $^{-1}$.

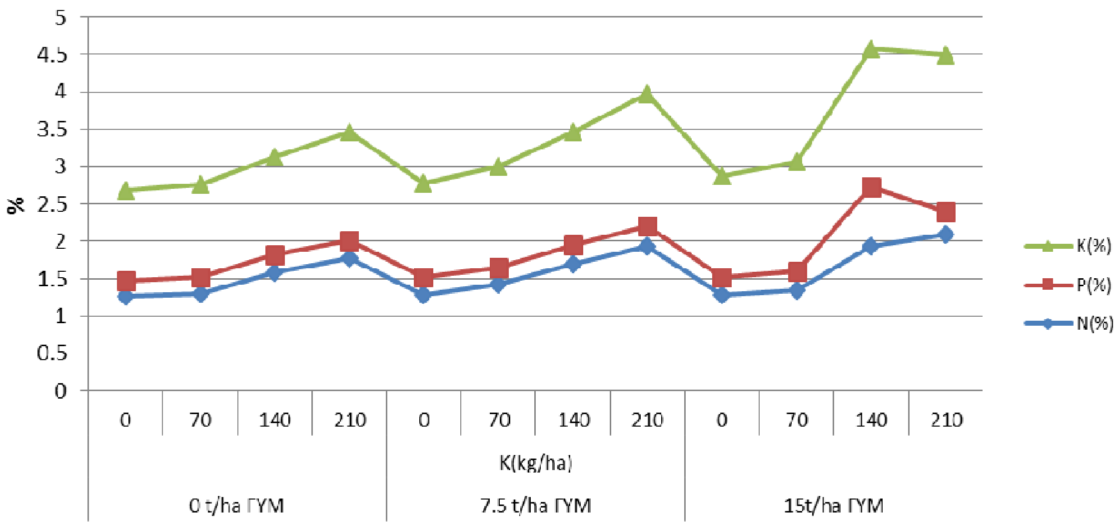

Figure 1. Interaction effects of FYM and K application on N, P and K content of tubers

An accumulation of 4.5 g K 100g $^{-1}$ dry tuber was recorded in this experimental condition. This might be attributed to high K uptake efficiency facilitated by the FYM or organic matter. In general, FYM and K fertilizers interaction at acidic soils of East Gojjam yield better quality of potato tuber. Better tolerance for disease and frost has been observed.

3.5. Interaction effect of FYM and K on tuber processing quality (starch and sugar)

The test of tuber tissue for starch and sugar content (processing quality) depicts that the interaction of FYM and K (SOP) produced significant positive improvement. As can be observed in Figure 2, starch composition of up to13% was obtained at 15 t and 140 kg K ha^{-1}. In most experiments starch content in tubers is seen to positively correlated to potassium application. 1.8 % K in tuber dry matter is reported to be necessary for high starch concentration. This experiment confirms that SOP was found to be better in this respect. Further, it was observed that SOP application also helped in decreasing the content of reducing sugars in the tubers which in-turn improved the chip quality as higher content of reducing sugars leads to browning of chips on frying.

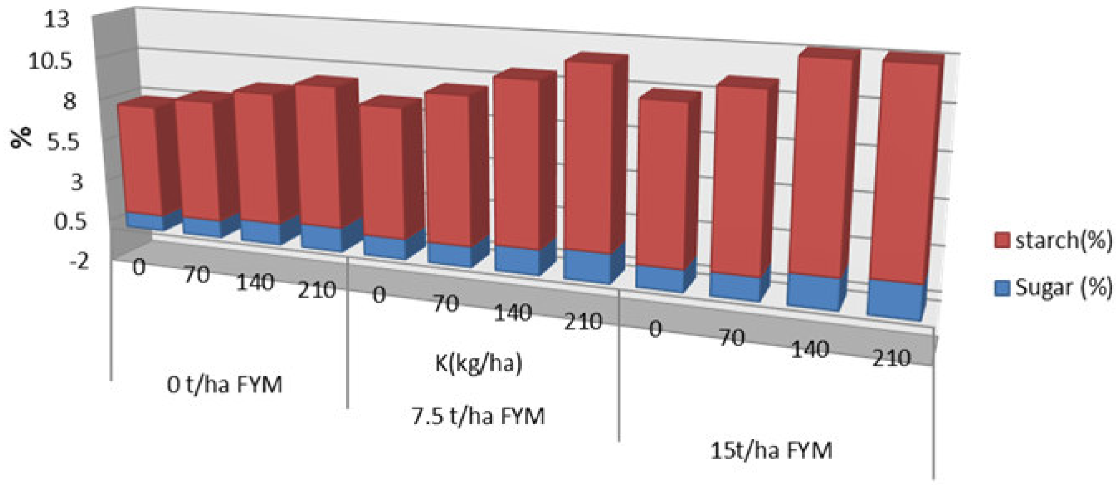

Figure 2. Interaction effects of FYM and K application on processing quality of tubers

In addition, Rajanna et al. (1987) found that potassium fertilizer increased starch, total sugar and reducing sugar. In general, co-application of 15 tons of FYM and 140 kg of K ha $^{-1}$ are best to produce quality processing quality potato tuber in acidic soils of Gozamin wereda.

3.6. Yield and yield components

The yield and yield components did not have any response to FYM and K interactions. However, main factors influenced positively and significantly (P = 0.05) the yield and yield components (Table 3). As can be seen , Sp gravity, DMT and TTY have been significantly affected by 15 t ha^{-1} FYm and the three levels of K compared to the control (0 levels).

Table 3: Potato yield and yield components as affected by main effects

FYM (t/ha)	Specific gravity	Dry matter of tuber (%)	Total tuber yield (t/ha)	Tuber nr/hill	Fresh wt of tuber (gm)
0	1.04a	20.35a	23.2a	4.4a	0.44
7.5	1.06b	20.63b	25.87b	5.4a	0.46
15	1.07c	21.2c	23.2c	5.9a	0.46
LSD (0.05)	0.01	0.17	0.53	0.2	0.12
CV (%)	1.06	14.76	2.39	2.56	12
K_2O (kg/ha)					
0	1.04c	20.48b	23.92a	5.3a	0.48
70	1.06b	20.60b	24.69b	5.9a	0.48
140	1.06b	20.61b	20.61c	6.52b	0.51
210	1.07a	21.23a	29.37d	6.6b	0.52
LSD (0.05)	0.01	0.19	0.6	0.60	0.14
CV (%)	1.06	14.76	2.39	3.5	11

However, tuber number was not significantly affected by the FYM and K application. On the other hand, our results did not agree with those of Davenport and Bentley (2001) and Abdelgadir et al. (2003) who found that specific gravity did not respond to K application.

4. Conclusion and recommendation

As a tuber crop, potato responds well to K and FYM in terms of tuber yield and processing quality parameters**.** Each levels of the factors had progressive response to all parameters considered. The interaction effect, however, had more pronounced effect on the quality components than the yield aspects. The soil test and tuber parameters in general confirmed that the soil needs K fertilization in addition to N and P that has been there for more than four decades. Moreover, the effect of K on tuber processing quality improvement is apparent. This effect is magnified as FYM was co-applied with it.

In the future, integrated nutrient management research should be conducted. Based on the availablity, compost and vermicompost materials should be tested and verified as an alternative organic fertlizer source in the area.

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